An appropriate stocking size of juvenile Japanese flounder, *Paralichthys olivaceus*, in consideration of carrying capacity

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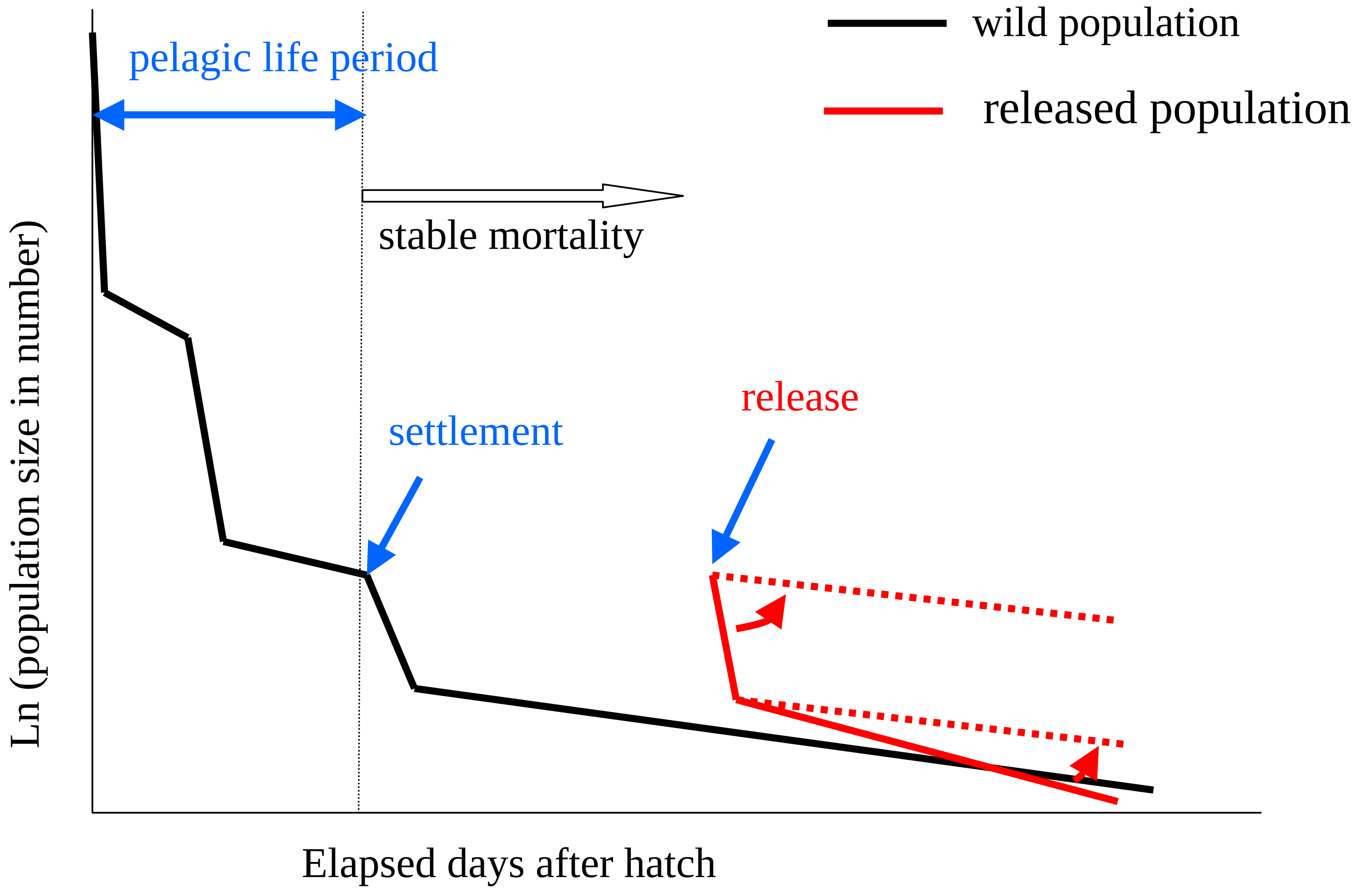
Schema of stocking Japanese flounder



Stocking technique (size, timing, etc) are decided to increase the economic return rate which is determined by a balance between cost and benefit.

Economic return rates (ERR)

= estimated financial returns / hatchery costs

for four main stocking target species

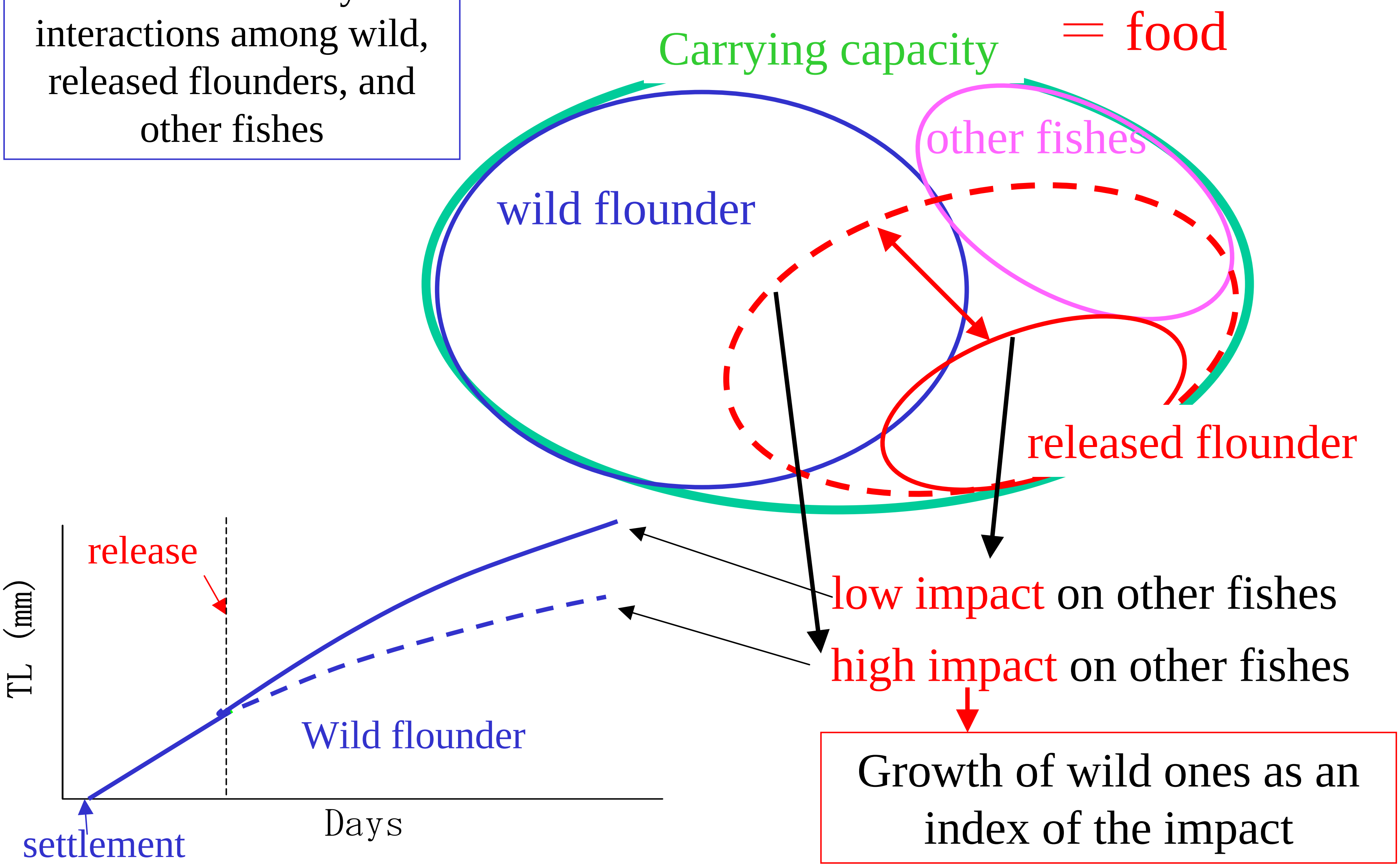
Species	Sample size	Animal size (cm)	ERR
Chum salmon	9	5	9.1 (6.6-11.3)
Scallop	36	3.5	26.4 (0.5-294.1)
Red sea bream	6	7	4.5 (2.9-7.3)
Japanese flounder	13	7 – 10	2.0 (0.4-3.4)

from Kitada (1999)

size of fish, timing, environment

To reveal whether released fish contributes to increase in abundance of wild population or only replace it, interactions among released, wild fish, and other species should be studied.

Schematic of study on interactions among wild, released flounders, and other fishes



How much one can release juveniles without any impacts on the growth of wild flounder?

Objectives

1. To construct a model which reproduce the growth of both wild and released flounders using actually observed parameters.

2. To evaluate an appropriate stocking size at which released juveniles do not have any impact on the growth of wild ones by means of the model.

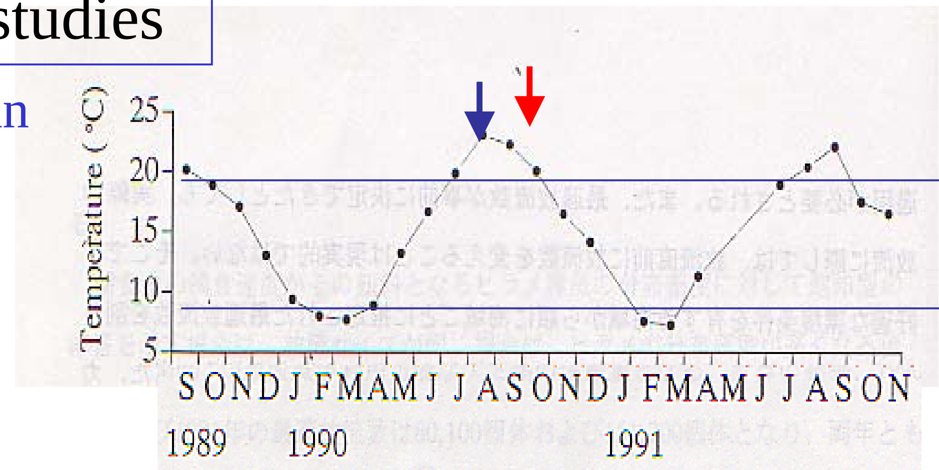
Field studies

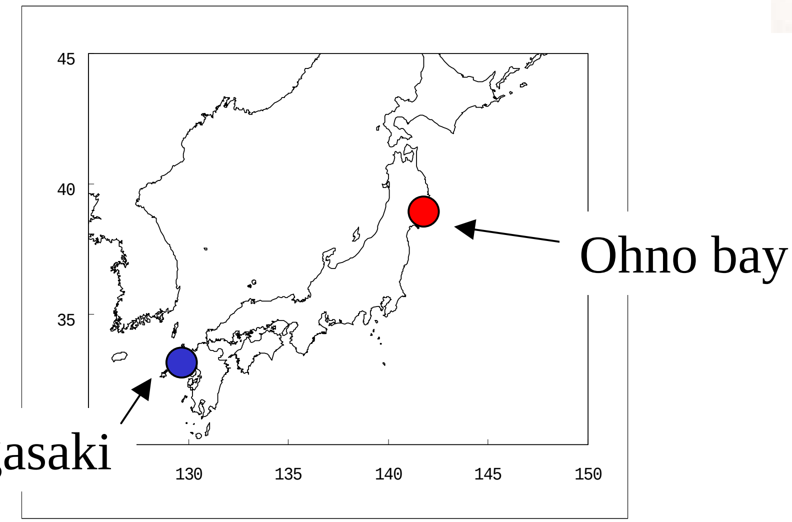
Study area: Ohno Bay, northwest of Japan

500 × 500 m

Settlement: early August in 1989

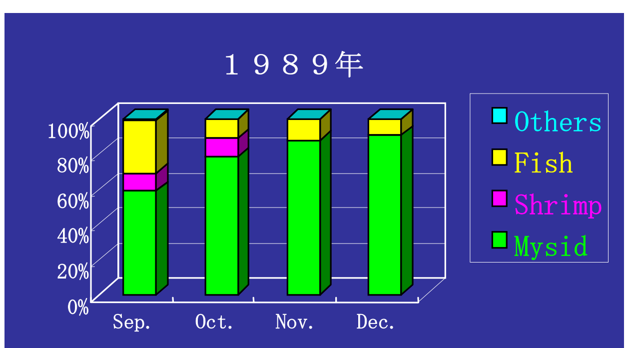
Release: 76,000 inds. on 5 Sept

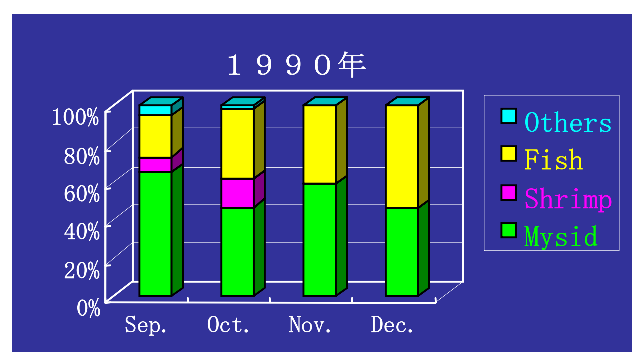




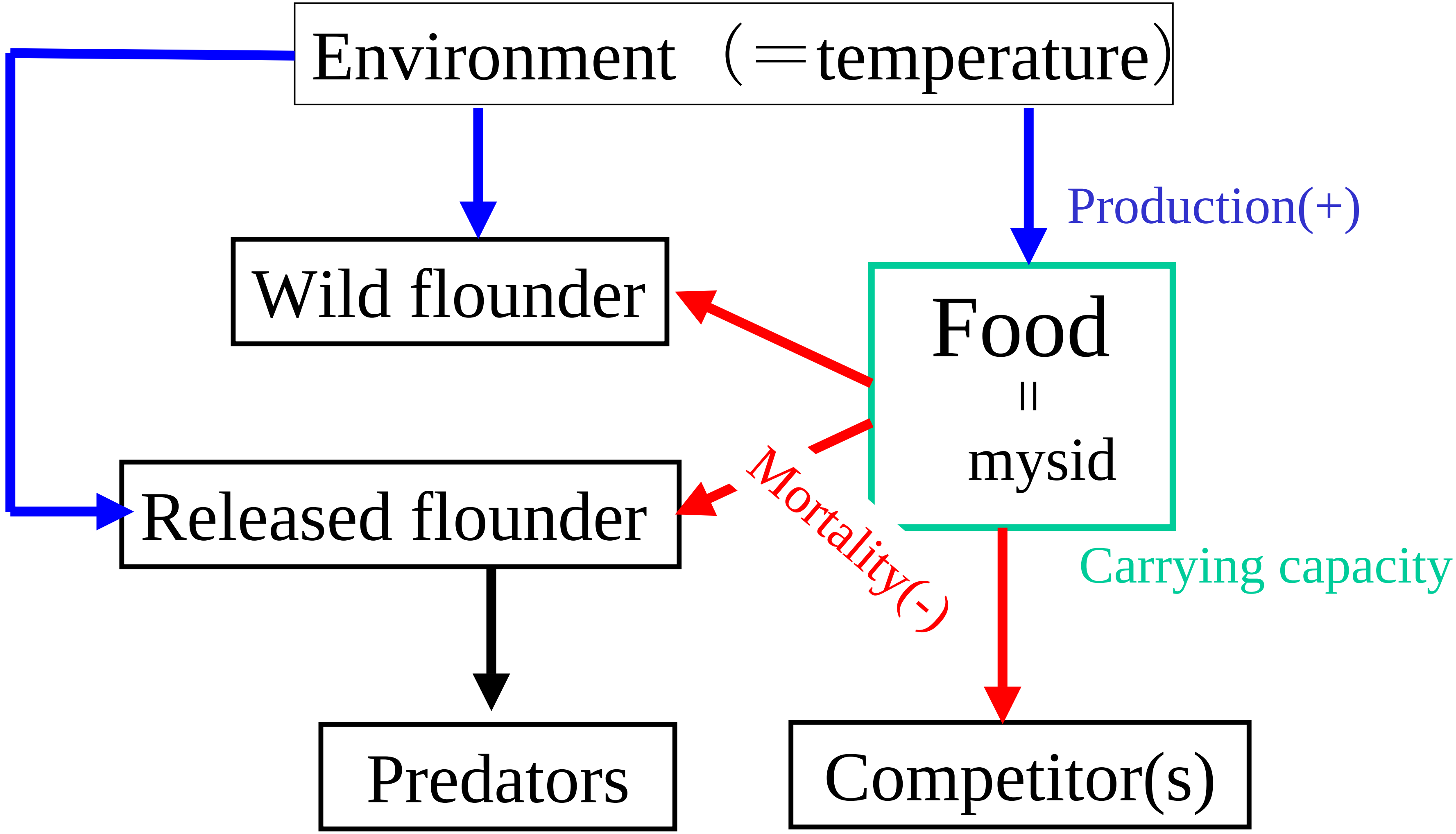
Feeding

Japanese flounder feeds mainly on a mysid, *Acanthomysis mitsukurii*. ミツクリハマアミ





Framework of the model



・Biomass of mysid (main food of the flounder, an index of carrying capacity) fluctuates under the influence of varying production and mortality.

・Growth of the flounder changes as a consequence of fluctuating biomass of mysid and temperature.

Varying biomass of the mysid, *A. mitsukurii*

$B(t+1) = B(t) + P -$ Natural mortality $-$ Predatory mortality

B,biomass; P, production

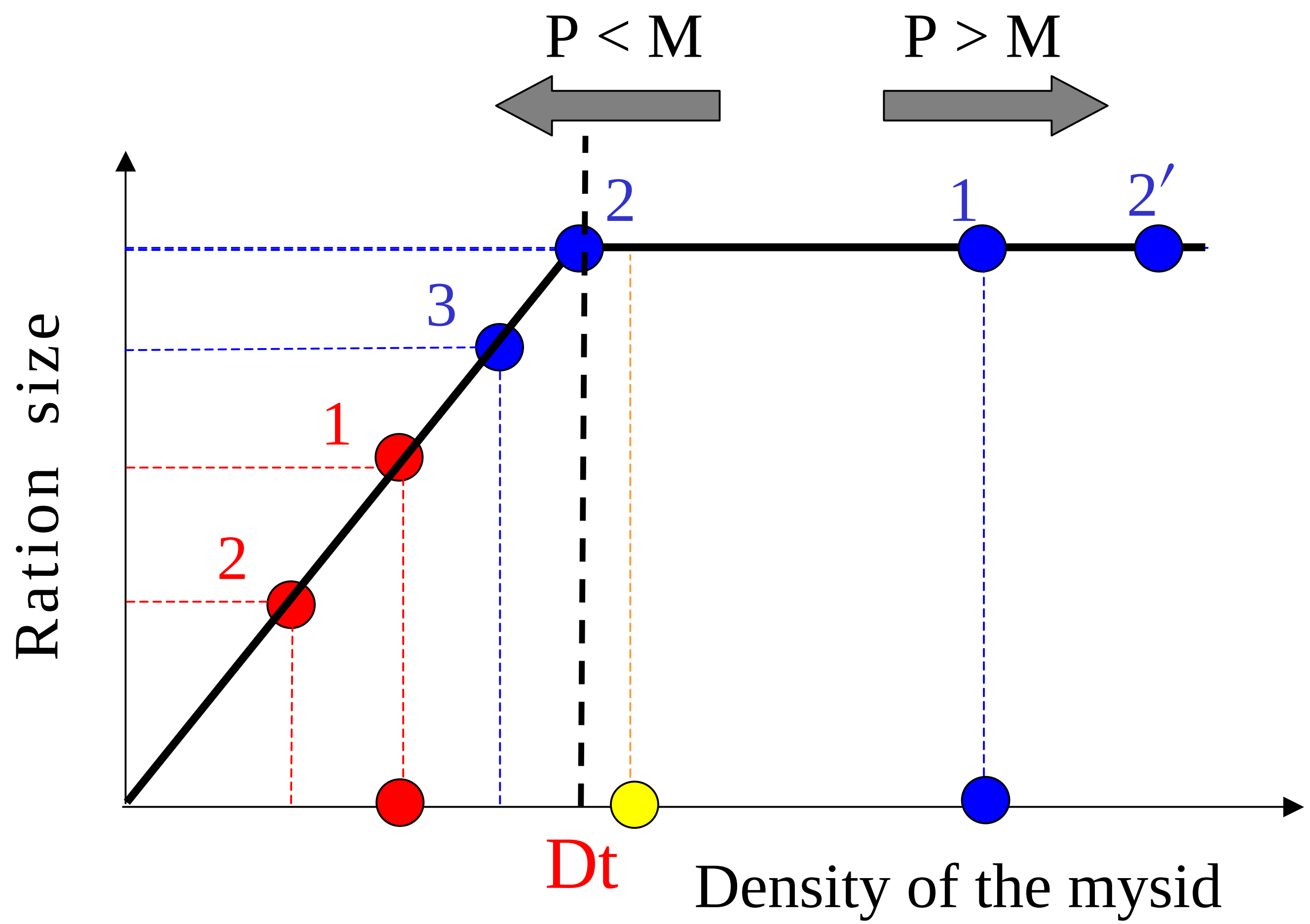
$P = B \times 0.05\exp(0.14 \times \text{Temperature})$ Yamada (2000) D. thesis

Predatory mortality by wild and release flounder and competitor(s)

Natural mortality: constant

$$\underbrace{B(t+1) - B(t)}_{\gtreqless\ 0} = \underbrace{P - (\text{Natural m.} + \text{Predat. m.})}_{\gtreqless\ 0}$$

Relationship between ration size of the flounder and biomass (density) of the mysid



Density of the mysid > Dt → Ration size = const. (max)

Density of the mysid < Dt → Density ↑ Ration size ↑

Density ↓ Ration size ↓

Allowable stocking size changes due to the initial density of the mysid at releasing and a balance between production and mortality.

Parameters for the production model at a subpopulation level

Study area

Ohno bay　500×500 m, 0〜10 m deep

5 Sept (releasing) 〜 9 Nov in 1989 (65 days)

17.2 → 13.2 ℃ (bottom temperature)

Size of subpopulation of the flounder

	Wild		Released	
5 Sept	43,575 inds	43.2 mm TL	76,000 inds	91.9 mm TL
9 Nov	5,270 inds (12.1%)		2,958 inds (3.9%)	

Feeding

the flounder < 50 mm TL; feeding on only the mysid

the flounder > 50 mm TL; feeding on the mysid

40 % of the satiated ration size are given

Parameters

Production of the mysid

B（t＋1） ＝B（t） ＋P－ Natural mortality － Predatory mortality

P ＝B × 0.05exp （0.14×Temperature）

Competitor

Tarphos oligolepis (アラメガレイ）, a small flounder < 60 mm TL

Age 0+; 5,450 inds, feeding on the mysid as much as 16 % of body weight

Age 1+; 1,580 inds, feeding on the mysid as much as 3 % of body weight

Predators, feeding on only the released flounder

Japanese flounder 1+,2+

A greenling *Hexagrammus otakii* (アイナメ）

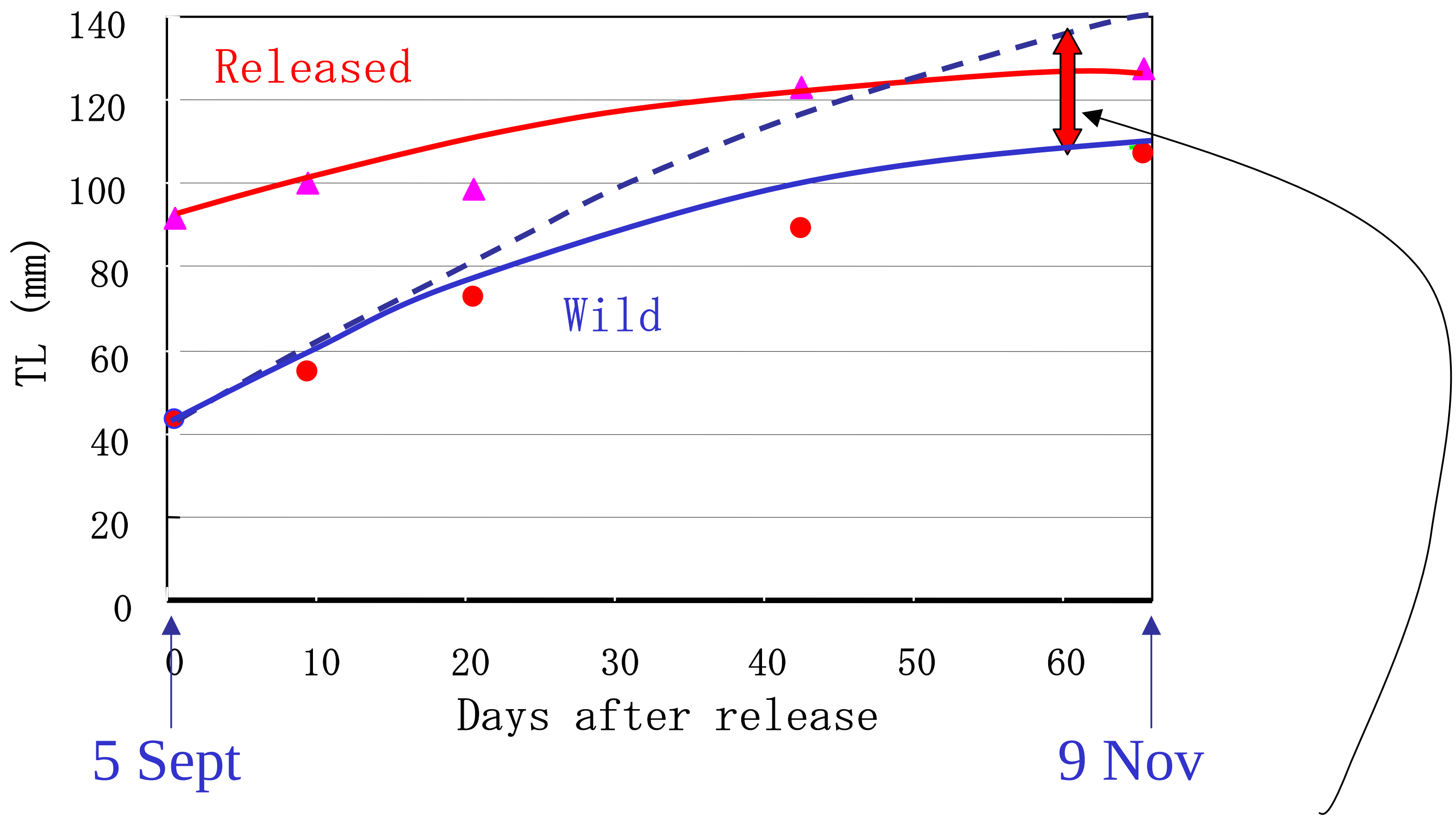
Temporal variation in the amount of predation follows the results of field observations.

Growth of the wild and released flounder

predicted vs. observed

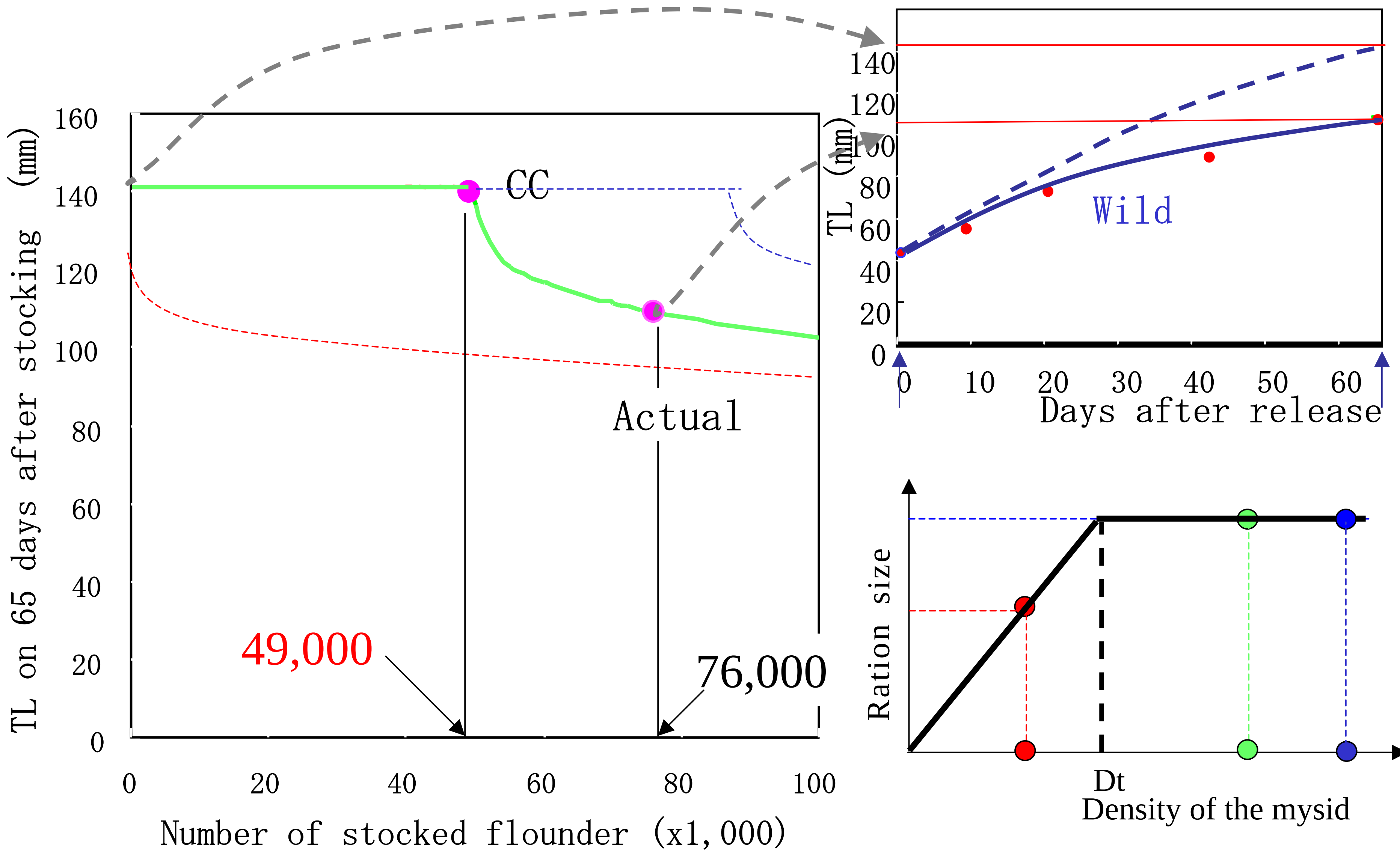
observed
predicted
with 76,000 released fish

predicted without any released fish



Releasing 76,000 inds has retarded the growth of wild fish.

An appropriate stocking size below which the growth of wild flounder would not be restricted by released flounder, being predicted by the model applying to the conditions at Ohno bay in 1989



Conclusions

We developed a model which can predict the growth of wild and released Japanese flounder at a shallow sandy area.

This model consists of 5 compartments (mysid, wild flounder, released flounder, competitor, predators) and considers the interactions between them under varying temperature.

An appropriate stocking level was estimated with the model under the criterion that hatchery-raised flounder would not retard the growth of wild one. The appropriate level at Ohno bay in 1989 was 49,000 inds. while actual level was 76,000.

Parameters should be adjusted to apply this model to other areas and years, however, a framework is constructed.

This study will be soon submitted to “Fisheries Science.”